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IPv6 Test Methods: General Description and Validation

National Institute of Standards and Technology

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Reports on Computer Systems Technology

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Executive Summary

This document forms part of the USGv6 Testing Program. It is specifically directed at

- Accreditation organizations who are signatory to the International Laboratory Accreditation (ILAC) mutual recognition arrangement,
- Testing laboratories who will apply to such an accreditor for USGv6 profile testing accreditation, and
- Test method developers who develop abstract and/or executable tets and test methods for USGv6 capable hosts, routers and network protection devices.

Taken together with the abstract test specifications published at the USGv6 testing website [14] it provides the essential material for accreditors to establish testing programs compliant with ISO/IEC 17025 [3] and for test laboratories to seek accreditation for USGv6 test methods. The motivation for this testing program follows from the publication of NIST SP 500-267 "A Profile for IPv6 in the U.S. Government – Version 1.0[1]" [2] which provides recommendations to Federal Government agencies for device level acquisitions in the adoption of IPv6. In that document we suggest that "product testing services are likely needed to ensure the confidence and to protect the investment of early IPv6 adopters". We surveyed the existing IPv6 testing programs, and concluded that a distinct USG testing program is needed, but with the commitment to harmonization and convergence into a broad collaborative user/vendor testing initiative, in which the technical and procurement requirements of the USG can be accommodated.

Among the existing IPv6 testing schemes both the IPv6 Ready Logo [7] and the DoD IPv6 capable certification testing process [8] embrace conformance testing and interoperability testing of IPv6 hosts and routers. As of March 2009 the DoD has ceased separate testing of IPv6 products in favor of testing to Unified Capabilities Requirements [15]. The IPv6 Ready Logo uses abstract test specifications, subjected to member review, and interoperability testing allowing for a flexible range of network architectures. Their device requirements are defined implicitly using abstract test specifications for a range of Core + Applications + other functions. NIST has signed memoranda of understanding with appropriate members of the IPv6 Ready Logo program to secure use of their test specifications as the initial basis for the USGv6 Test Program. As this test program evolves, selected subsets of these tests, possibly with modifications and additions necessary to address specific requirements of the USGv6 Profile, will be published.

The USGv6 Test Program is designed to support multiple independent and autonomous test laboratories, and first, second and third party testing scenarios. In order to promote general confidence in test results in this environment and to insure both reproducibility and equivalence of test methods, the USGv6 Test Program requires that tests be conducted at ISO/IEC 17025 [3] accredited laboratories.. The means by which the test methods of a given laboratory are accredited are the main subject of this publications.

The IT accreditation landscape has changed in recent years. Where it was once possible to designate a single, usually government-run accreditor, there is now competition from private accreditors who compete on a level playing field. The laboratory accreditation organizations qualifications include compliance with ISO/IEC 17011 [4], and being signatory to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Agreement (MRA) [16]. In order to promote comparability of test results across the accredited testing laboratories we encourage qualified accreditors to collaborate with NIST in the development of IPV6 testing specific accreditation requirements in addition to the general requirements of ISO/IEC 17025 [3] in the accreditation of IPV6 testing laboratories. This document is intended to provide guidance to any and all accreditors and test laboratories on units of

[1] Hereafter known as the USGv6 profile.

accreditation, standard reference tests, test method validation criteria, and, crucially, feedback mechanisms to maintain quality improvement in test suites, in addition to maintaining consistency of test interpretations.

Securing the network is criticial, and the USGv6 profile includes provisions for IPsec and for edge protection devices such as firewalls, collectively known as network protection devices (NPDs). NPD testing involves functional testing, local interface, environment, and document inspection. We are working to establish NPD test suites that can serve as an authoritative reference, in addition to the unique procedures written in this document.

The type and quality of information supplied by the laboratory to device vendors, and by devices vendors to customers, are critical to the accurate representation of the product. The USG supports the use of Supplier's Declarations of Conformity (SDoC) [5,6] based on test results from an appropriately accredited testing laboratory. In this scheme, the product is conformance and interoperability tested in accredited laboratories, and based on a review of the test results and the requirements of this document the supplier issues an SDOC recording the description of the product as tested.

1 Introduction

This document has been prepared for use in conjunction with NIST SP 500-267 A Profile for IPv6 in the U.S. Government [2]. It can be used by nongovernmental organizations on a voluntary basis and is not subject to copyright, though attribution is desired.

Nothing in this document is intended to contradict standards and guidelines made mandatory and binding on Federal agencies by the Secretary of Commerce under statutory authority, nor ought it be interpreted as altering or superseding the existing authorities of the Secretary of Commerce, Director of the Office of Management and Budget, or any other Federal official.

1.1 General Discussion of IPv6 Device Testing

The USGv6 profile defines requirements for host, router and network protection devices (NPD). Each of these device types defines a set of unconditional mandatory requirements, and provides several sets of "configuration options" that provide additional requirements that can be selected at the discretion of the profile user. Individual technical requirements are categorized as being mandatory, conditionally mandatory (based upon configuration options), or optional.

It has become the practice for networked devices to be subjected to two different types of testing, for interoperability and for conformance (IPv6 Ready Logo [7], JITC [8]). Conformance tests a node against the protocol specification, and usually involves testing against protocol specific test devices or test tools. Interoperability tests nodes' ability to interwork in multi-vendor groups, over single or connected subnetworks. In a mature technology line, interoperability is prioritized over conformance, since the ability to communicate with the installed base is paramount. While the interoperable base is small , it is easier for a few implementors to make agreements yielding interoperability without strict conformance. For this reason, the results of conformance testing assume a greater importance earlier in a technology's lifecycle.

As a prudent step to secure procedurally correct testing, the USGv6 testing program requires that testing be done in laboratories accredited for the test methods in this document in accordance with ISO/IEC 17025 [3]. That standard refers to general testing requirements and so this document specifies the technical test methods involved in IPv6 device testing. This embraces both the conduct of each type of testing and the validation of test methods.

The foundation of each testing framework is a set of published test specifications, traceable to the consensus protocol standards. An initial basis set of abstract tests have been made available to the USGv6 testing program through agreements with IPv6 Forum members and the IPv6 Ready Logo program [7]. This provides coverage for some, but not all of the requirements in the USGv6 profile. For every abstract test specification, and corresponding executable test method, there must be a validation plan. abstract test specifications are initially validated against protocol specifications or standards. This is necessarily an informal heuristic step, as the RFCs underlying the profile are informally written in natural language text[2]. Even so, this process gives some confidence in the integrity of the abstract test specifications so that executable test methods can be validated against these abstract test procedures. Conformance, interoperability and network protection device (NPD) testing have different traceability chains, and these are further detailed below. Tests, like software, are always works in progress. In continuous operation there will be bugs, and needed interpretation. In order to converge on a truly interoperable community, it is necessary that tests be maintained in synchronization across all participating laboratories, and test interpretations be agreed among laboratories, test method suppliers, producers and specifiers.

The end result of a product test from the laboratory's point of view is a set of test results, as run and evaluated by the laboratory. We recommend that product suppliers document successful completition of testing at an accredited laboratory using a Supplier's Declaration of Conformity, compliant with ISO/IEC 17050 Part 1[5,6] and the specifics given in Section 8 of this document. This document MUST be supported by a summary of results indicating profile requirements supported[3] and the information compliant to ISO/IEC 17050 part 2 [6]. These documents will specify the hardware and software configurations tested and the other implementations with which it has been tested and found interoperable.

1.2 Purpose, Scope and Document Structure

This document describes the test methods and traceability requirements necessary to operate a test laboratory for USGv6 profile compliance requirements. This includes conformance and interoperability testing of hosts and routers, and network protection device testing. Specific elements include: quality components, traceability of tests, test feedback mechanisms, scopes of accreditation, test method validation and interlaboratory comparison, test pass requirements, and claims of compliance.

The primary source of information on the management of the USGv6 testing program is the project website [14].

Quality Components

ISO/IEC 17025 describes general procedures for constructing and assessing test laboratory quality systems. It does not describe test method specific competencies. Accreditors develop free-standing testing programs based on ISO/IEC 17025 and incorporating test methods from the technical domain. For USGv6 those test methods are described in here.

Traceability of Tests

At the root of the testing hierarchy is the set of base technical standards. For IPv6 these include the set of RFCs specified in natural language text by the Internet Engineering Task Force (IETF). Abstract test specifications are derived from these, describing also in natural language the configurations and

[2] As opposed to a formal language specification.
[3] The UGv6-V1-Capabilities checklist in Appendix A of the USG profile offers a model for this.

procedures for testing the RFC functions. Since these are in natural language, the validation method to determine the correctness of these tests is informal expert review, according to systematic procedures published in here. We distinguish between test validation for conformance and interoperability and for NPD functional testing, in Section 4.1.

Feedback Mechanisms

In a technology as complex as IPv6, with upwards of 150 RFCs referenced in the profile, test coverage and correctness become an extensive management issue. It may be that the community of test laboratories discovers the need to alter, add or delete certain tests. We propose an assessment framework that makes sure test case fixes are communicated among, and agreed between, participating test laboratories, in Section 4.4.

Test Methods and Scopes of Accreditation

The USGv6 profile [2] defines a range of capabilities applicable to configurations of host, router and NPD devices. All devices must implement the IPv6 Core specifications (RFC 2460 et al)[4]. All devices must implement the IPsec suite (RFC 4301 et al) – its function relies on the core, but its testing is separate. Optional groupings include also Mobility (RFC 3775 et al), Multicast (RFC 3810 et al) and Network Management (RFC 3411 et al). Network protection devices also require to be tested, and these include Firewalls, Application Firewalls, Intrusion Detection Systems and Intrusion Protection Systems. Their functions are directly specified in the USGv6 profile Section 6.12 [2]. All of these functions are subject to discrete test methods. Assessment for Accreditation requires a combination of these methods. An individual test laboratory may choose to test one or more device types, and provide one or more of these test methods. No test laboratory is obliged to provide all test methods. The list of test methods and Scopes of Accreditation can be found in further detail in Section 5.2.

Test Method Validation

The complexity of IPv6 functional categories is paralleled by complexity in Test Methods, over all types of testing. There are different validation requirements for conformance, interoperability and network protection device test methods. Test laboratories accredited for conformance use test methods comprising software and test scripts to achieve the test purposes of the abstract test specifications. Validation of these test systems entails resolving the behavior and outcomes of executing these tests, against the respective abstract test specifications. The informality of the RFCs and ATS limits this also to being an informal, heuristic process. Test laboratories accredited for interoperability use procedural test methods for constructing heterogeneous configurations of hosts, routers and NPDs, using test traffic generators, and observing the results with respect to devices under test. Validation of interoperability test methods is performed through review of test procedures and their execution, by many technical experts. The procedures for validation of conformance and interoperability test methods are described in Section 6.1.

Network Protection Devices act as inline filters to analyze and block or permit traffic flowing into and out of a protected network. The presumption is that they can be compromised either physically, or by packet flows in either direction. They include requirements for managing packet traffic, configuring filters, logging, user documentation and administrative security. Testing of NPDs is required not only to exercise packet traffic flows, but also to exercise administrative functions to assess the integrity of logged messages, and to assess the documentation. Generally, validation of the functions of filters, administrative control, logging and documentation will be through manual analysis. This is detailed in Section 6.3.

[4] The set of RFCs and other protocol specifications within the scope of this testing document are fully specified in the bibliography of the USGv6 profile [2].

Proficiency Testing and Interlaboratory Comparisons

As part of assessment for accreditation, the laboratory and its staff undergo proficiency testing to determine the laboratory's competence to apply the test methods within its scope. As a related, but separate issue, each laboratory must be able to show equivalence of results among identical products tested in any laboratory that operates the USGv6 test program. Proficiency testing and interlaboratory comparisons are described in Section 7.

Claims of Product Compliance

The output of the testing process using validated test methods described in this document include a test report summarizing tests passed and failed, and providing detailed IPv6 packet data results. This is useful for product vendors to verify and improve their devices. They need not choose to give all detailed results to purchasers.

In this program, claims of device compliance take the form of a Supplier's Declaration of Conformity, as specified in ISO/IEC 17050 parts 1 and 2 [5], [6]. Part 1 sets requirements for the supplier's declaration or attestation of conformity and provides information identifying the product, producer and requirements and Part 2 identifies the needed supporting documentation. The test report mentioned above forms part of the documentation, and this is further supported by the traceability hierarchy that is the subject of this document. Section 8 elaborates the requirements and constraints of the SDoC. This includes also a discussion of the Test Pass requirements for each method and functional category.

1.3 Lifespan

The provisions of this testing guidance document remain in effect through the lifetime of the successive versions of the USG profile. Active USG management of the USG testing program will continue at least 24 months beyond the last iteration of the profile. The timing of cessation of active management is to be determined. It is our intention to secure continuity through merger with other testing programs.

However, the total lifespan of USG Profile compliance testing includes within it a lifecycle model that encompasses changes to the profile and to the test specifications that have impacts on the developing Interoperable base. This lifecycle model is discussed on the USG IPv6 testing website [14][5].

1.4 Audience

This document is tied to the USGv6 Profile [2], and in general all parties having an interest in the profile, have also an interest in the testing program. The set of stakeholders is depicted in Figure 1.

Accreditation organizations assess, audit and accredit test laboratories by scopes of accreditation, which are aligned with test methods. The methods defined in this document are therefore crucial for setting up any accreditation program. The requirements applied by the accreditors are vitally concerned in the traceability of standard reference materials defined here as well as the quality provisions for maintaining and improving test specifications.

Testing laboratories seeking accreditation will use the document to acquaint themselves with the test methods for conformance and interoperability of hosts and routers, and network protection. They are also interested in the test method validation mechanisms, and both quality improvement and global synchronization aspects of bug reporting and resolution.

[5] Subject to development while this document is in draft.

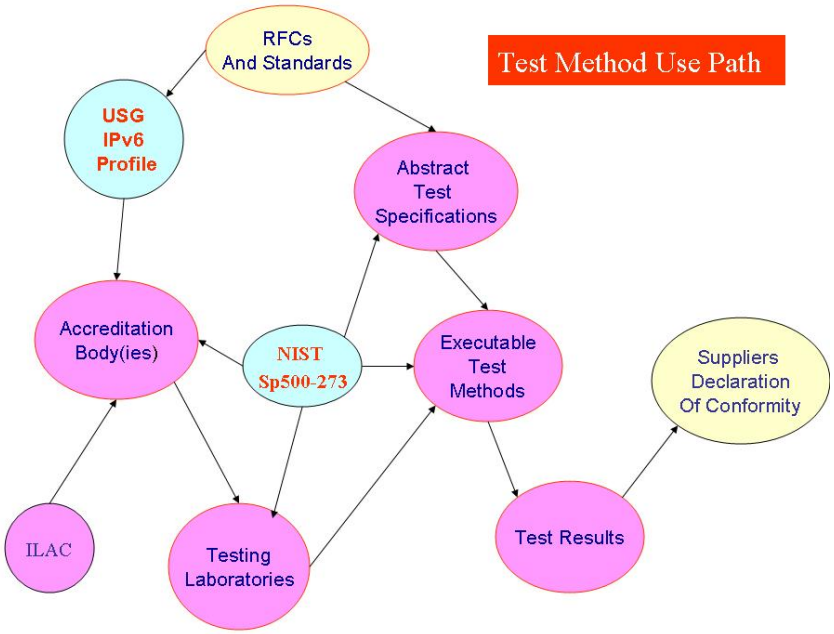

Figure 1: Relationships Between Participants in this Testing Program

The testing program associated with this document draws on abstract test specifications originated by members of the IPv6 Forum. The format and standards of coverage of these test specifications provide the basis for confidence in the integrity of the test results. Developers and maintainers of these specifications are therefore interested in any constraints these guidelines may place on them. Similarly, developers of executable test methods are interested in the validation criteria inherent in the traceability hierarchy here.

This document details the reporting criteria for the Suppliers Declaration of Conformity (ISO/IEC 17050), and IPv6 product developers also have a stake in its provisions.

1.5 Normative Terminology

The terminology used to describe requirements levels in the profile include: “mandatory”, “optional” (with their common meaning), and "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" which are to be interpreted as described in RFC 2119 [13]. In addition, the profile adopts the use of the term “SHOULD+”to indicate a requirement that is equivalent to “SHOULD” in this version of the specification, but is expected to be elevated to a “MUST” in future versions.

The use of MUST, MAY and SHOULD within this testing document refers to the requirements for testing, as distinct from the requirements for IPv6 device implementation. More commonly, requirements in this document are expressed as declarative text.

2 Linkage to the Accreditation Infrastructure

There has been for many years in industrialized economies a system where acquisition authorities and government entities require compliance to particular standards. Test laboratories are established to test artifacts and systems against reference materials. National measurement laboratories such as NIST in the United States, and the National Physical Laboratory in the United Kingdom develop methods for improving precision in measurements of standard reference materials;.Accreditation bodies assess the integrity of test laboratories use of the testing materials, and create an umbrella for the community of test laboratories so that the results from every lab are equivalent.

The International Laboratory Accreditation Cooperation (ILAC) operates a peer assessment system to provide confidence in laboratory accreditation. ILAC MRA signatories operate in accordance with the standard for accreditation systems, ISO 17011 [4]. One or more qualified accreditors may be interested in establishing programs of accreditation for IPv6 testing laboratories.

2.1 The Role of the Accreditor

Qualified Accreditors include those bodies compliant with ISO 17011 [4] who are also signatory to the International Laboratory Accreditation Co-operation (ILAC) Mutual Recognition Agreement. When such an accreditor establishes an accreditation program, there are three components: quality, technical test method, and interlaboratory coordination:

- Assessment of the testing process, laboratory management, and quality control. These are covered by implementing ISO 17025 [3], General Requirements for the Competence of Calibration and Testing Laboratories. This is the quality component.

- Assessment of the operation of the test method, and validation of the test method. This is the technical component, and for our purposes the technical content includes conformance and interoperability testing of IPv6 devices, and functional testing of network protection devices.

- Oversight of the coordination between test laboratories participating in the IPv6 testing program. Because of the potential for multiple accreditors entering the IPv6 space, it is particularly important to coordinate comparability of test results from accredited laboratories across test methods, devices and test laboratories results.

The accreditor must look to this document for the second and third items above.

2.2 The Role of the Program Sponsor

Accreditors generally establish programs based on an expressed stakeholder need. The USGv6 Profile was authorized by the Office of Management and Budget Memorandum 05-22 [1], and published by NIST. The associated testing program is sponsored by NIST. The sponsor's role includes identifying the standard reference materials, test methods, and methods of validating operational tools against the reference standards. The content of this document is the expression of responsibility for establishing test methods for IPv6 devices under the Profile.

The program sponsor may also designate one or more agents to conduct and coordinate the program of interlaboratory comparisons discussed in Section 7.

Ongoing coordination between profile requirements and testing infrastructure is also provided by NIST, through the testing website [14] and the mailing list at usgv6-testing@antd.nist.gov.

3 Testing Frameworks

"IPv6" is actually a large and complex collection of protocols and functions necessary to define the new Internet Protocol (IP) as well as its implications for other protocol layers and the interfaces between them. There are ways to test this nexus of protocols by isolating particular protocols in particular devices, or by assessing the aggregate behavior of the aggregate devieces/network. The isolation testing methods include conformance testing, and also functional and security testing. Interoperability testing tests the aggregate behavior by providing a realistic test of a device's behavior in a networked system. There is no widely known and agreed published methodology for interoperability testing. There are "operational" definitions, including the scheme operated by JITC for the DoD, and the IPv6 Ready Logo scheme. The JITC scheme entails connecting the Device under Test (host, router, or other device allowed by the DoD Profile) to a configuration that emulates DoD's Global Information Grid (GIG), and running the tests published in the DoD Generic Test plan [8]. These generally involve operating end-user applications and analyzing the results.

The IPv6 Ready Logo interoperability testing scheme is defined operationally in the documents published at http://www.ipv6ready.org. It usually entails a configuration with one or more hosts under test, and one or more routers under test. If the Tahi interoperability toolkit (http://www.tahi.org) is employed, the configuration includes a test manager, open source reference devices, packet trace and analysis tools, and four connected subnetworks including one with Devices Under Test attached. There is great flexibility in creating the configuration of devices to test.

The common requirement for interoperability testing is one or more points of control and observation for introducing traffic and analyzing and interpreting results. Architectures vary, however, and some methods require testing against a particular enterprise network, while others emphasize testing against a diverse plug-and-play set of devices. Each of these methods has merit, but for preparing to introduce IPv6 devices into a general market, the second method seems most useful. The first method has merit in conjunction with acceptance testing, however.

For conformance testing, ISO 9646 [10] describes a rich set of methods including single and multi-layer methods, point-to-point or transverse methods, and methods involving explicit test protocol coordination, or by human coordination between the application end-points. Most current executable methods seem to be multi-layer, loosely coordinated types. Any methods from the full ISO 9646 range are permissible.

Network protection device capabilities must include very general device configurability, logging, environmental security and packet filtering. Testing these capabilities requires physical access and inspection. The testing framework must have local access to accommodate these needs.

Separate testing frameworks are required for the conduct of conformance, interoperability and network protection testing. A framework includes the test methods and the procedures required to validate and maintain them, and the broad constraints for the conduct of each of these types of testing. The constraints on testing conduct are given here.

3.1 Performing Conformance Testing

The elements required to conduct conformance testing include the following:

- Any host or router claiming conformance to the USGv6 Profile MUST demonstrate evidence of Conformance to the USGv6 abstract test specifications.
- Conformance testing MUST be done in a facility accredited to ISO 17025 by an organization which may be controlled by the product supplier (1st party), by the US Government (2nd party) or by an independent testing organization (3rd Party).
- The technical test methods for Conformance MUST follow and reference these guidelines.
- Devices to be tested MUST include USGv6 profile functions as given in Appendix A and the Node Requirements Table.
- For each functional category and USGv6 profile configuration option, testing MUST be according to the conformance abstract test specifications published at the USGv6 testing website [14].
- To claim conformity in a SDOC, a device MUST pass all of the tests associated with unconditional MUSTs and all those conditional MUSTs associated with claimed device functionality as per the USG IPv6 profile. Additionally, a device MUST pass all those tests for which functionality is claimed, associated with SHOULD functions in the RFC or standard.

3.2 Performing Interoperability Testing

The elements required to conduct interoperability testing include the following:

- Any host or router device claiming compliance with the USGv6 profile MUST demonstrate evidence of interoperability with three or more commercial implementations of IPv6, to include at least one each of a host and a router, where appropriate.
- Interoperability testing MUST be done in a facility accredited to ISO 17025 by an organization controlled by the US Government (2nd party) or an independent testing organization (3rd Party).
- The technical test method(s) for interoperability MUST follow and reference these guidelines.
- Until further requirements are specified, successful conformance testing as per Section 8.2 MUST be pre-requisite to the applicable interoperability testing.
- Devices to be tested MUST include USGv6 profile functions as given in Appendix A and the Node Requirements Table of the profile [2].
- For each functional category and configuration, testing MUST be according to the interoperability abstract test specifications published at the USGv6 testing website [14].
- For each unit of accreditation, interoperability testing among several devices MUST be conducted in a single laboratory. However for different units of accreditation, a product vendor may choose different laboratory and interoperability partnering arrangements, even for the same product.
- To claim compliance to the USGv6 Profile in an SDOC, a device MUST pass all of the tests associated with unconditional MUSTs and all those conditional MUSTs associated with claimed device configuration options as per the USG IPv6 Profile. Additionally, a device MUST pass all those tests for which functionality is claimed, associated with SHOULD functions.

3.3 Performing Network Protection Testing

The elements required to conduct network protection device testing include the following:

- Any network protection device (IDS, IDP, Firewall or Application Firewall) claiming conformance to the USGv6 profile MUST demonstrate evidence of functionality as specified in the USGv6 profile Section 6.12 [2].

- Network protection device testing MUST be done in a laboratory accredited to ISO/IEC 17025 [3] for the applicable IPV6 test methods by an organization which may be controlled by the US Government (2nd party), or by an independent organization (3rd Party).
- The technical test methods for network protection devices MUST meet the functional criteria specified here in section 4.2.4.
- To claim compliance in an SDOC, a device MUST pass the applicable tests that are associated with unconditional MUSTs and all those conditional MUST associated with claimed device functionality as per the USG IPv6 Profile. Additionally, a device MUST pass those tests for which functionality is claimed, associated with SHOULD functions in the associated specification.

4 Traceability of Tests

The objective of testing is to determine whether a device complies with a given specification. In physical artifact testing a comparison is usually made of test results of the device against the requirements of the specification, accurate to a stated uncertainty. For the purpose of assessing IPv6 devices, the specification is the USGv6 profile [2] and the compendium of RFCs it references. Applicable devices include hosts, routers and network protection devices. Tests are derived from the protocol specifications and verified in a peer evaluation processs, by test laboratories and test tool developers. These then serve as the traceability root against which executable tests are validated. This section establishes the traceability chains for conformance, interoperability and network protection, in Section 4.1. Validation procedures for each test specification are stated in Section 4.2.

A measurement result is complete only when accompanied by a quantitative statement of its uncertainty. NIST policy, as expressed in NIST Technical Note 1297, 1994 [11] is that measurement results be accompanied by such statements, and that a uniform approach to measurement uncertainty be followed. This is developed in Section 4.3. Test development is a discipline akin to software development, As such it benefits from a review process involving deep and wide analysis by many experts. This is a process of feedback and continual improvement.This is further elaborated in Section 4.4.

4.1 Traceability Chains

Conformance and interoperability tests are derived from the specifications in the same way, and interoperability test are analogous to multi-protocol, loosely coordinated conformance test methods. They differ principally in their purposes, and the fact that in interoperability, multiple devices are tested simultaneously, rather than in isolation. It follows that their validation and traceability can be the same, and this is detailed in Section 4.1.1. For Network Protection Devices, the USGv6 profile Section 6.12 is the specification. Validation and traceability methods for these are discussed in Section 4.1.2.

4.1.1 Traceability Chain for Conformance and Interoperability Testing.

Base Specifications: The RFCs and other specifications selected by the USGv6 profile (current version).

Reference Tests: Abstract test specifications for each device type (hosts and routers) for the combinations of base specifications that exist, these are listed at the USGv6 testing website [14].

Executable Test Methods: For each reference test suite listed, above, the executable test method comprises tests and test execution software and hardware. An executable test method may combine the tests of one or more abstract test specifications. The validation of these executable methods is described in Section 6, below. Validation MUST be conducted in an appropriately accredited test laboratory accredited with respect to the USGv6 Test Program.

4.1.2 Traceability Chain for Network Protection Testing

The system of traceability for network protection is the same in essence as above BUT the point of creation and validation is distinctly different because of the different realities of network protection strategy. The difficulty is that when a network protection test suite is developed it can only reflect known attacks, but new attacks are being created all the time. The NP test suite is therefore made obsolete with the accumulation of new attacks. It is therefore necessary when testing network protection devices to (a)

ensure that all current attacks are covered and (b) “think like an attacker” and develop new attacks for the purpose of testing, by exploring settings and parameters not explicitly written into the existing test suite. This process is labeled ‘exploratory’ testing.

Base Specification: USGv6 profile, Section 6.12 (current version).

Reference Tests: For each network protection device type: firewall, application firewall, intrusion detection system, intrusion detection and protection system, tests MUST be derived from the functions given in the base specification. Abstract test suites for these are listed at the USGv6 testing website [14].

Executable Test Methods: The test methods include written procedures as well as some automation. The reference tests establish the minimum set. NPD testing involves exploratory testing at the discretion of the laboratory. In order to retain traceability, the newly created tests must show their derivation from the specification and additionally the rationale for their deviation from the closest applicable reference test. Since the actual set of tests is constructed at the time of testing, the laboratory MUST apply and document a procedure for validating each of the tests developed at execution time, after live testing and before issuing the test report.

4.2 Reference Test Validation

Conformance and interoperability testing of hosts and routers is based on RFCs and other natural language specifications. Apart from differences in the scope of test purposes and testing configurations, the tests are broadly similar in construction. We should expect their validation also to be similar. These are laid out in Sections 4.2.2 and 4.2.3 below. Network Protection device testing differs in purpose, scope and method. Its validation is described in Section 4.2.4.

4.2.1 General

- The USGv6 Profile is the compendium document that lists RFCs and other standards, which are the base specifications that abstract test specifications for conformance and interoperability are derived from.
- RFCs are written in natural language text and therefore they are informal. Any tests derived from these are also informal.
- Target devices for conformance and interoperability testing include hosts and routers.
- The impetus of validation comes from the uncertainty of the method of deriving test specifications from RFCs. Since protocol specifications are written in natural language, the general answer to this is that there is no formal proof, therefore we must use heuristic, “trial and error” methods to increase our confidence in the test.
- For each abstract test specification, the set of RFCs contained shall be analysed for testable functionality, including not only MUST and SHOULD designated functions, but also functions specified by imperatives and declarative statements in the running text.

4.2.2 Conformance

- Conformance test topologies include a target device under test, and one or more pieces of test equipment connected over an IPv6 network. These will typically be in the configurations described in ISO 9646-2 [10], and are distinct from interoperability testing configurations.

- Conformance abstract test specifications include a test purpose, reference to RFCs or standards, setup information, a procedure describing packet flows and packet field values, and an observable result. For convenience of reference they also include a systematic test identifier and/or title.

- The objective of a conformance test is to determine whether a device under test can realize the isolated behaviors specified in a set of RFCs or standards.

- For conformance testing, the coverage criteria recommended are those given in ISO 9646-2[6], Sections 10.1 to 10.4 [10]. Validation of abstract test specifications for conformance mirrors these procedures.
- Validation is the procedure that resolves the abstract tests against the RFC functional analysis.

4.2.3 Interoperability

- Interoperability test topologies include one or more target devices under test, one or more host or router reference devices, or test equipment including traffic generators and logging/analysis tools.

- Interoperability abstract test specifications include a test purpose, reference to RFCs or standards, setup information, a procedure describing packet flows and packet field values, and an observable result. For convenience of reference they also include a systematic test identifier and/or title.

- The objective of an interoperability test is to determine whether a device under test can realize the aggregate behaviors specified in a set of RFCs or standards.

- In all types of interoperability testing, actual IPv6 nodes communicates with each other. Traffic is driven through applications at one or more nodes. The construction, purposing and analysis of tests are not otherwise different than conformance. The validation methodology is the same, allowing for these architectural differences.

4.2.4 Network Protection

- The USGv6 profile Section 6.12 [2] is the base specification for network protection devices (NPDs). NPD tests are traceable to this specification.
- Testing, traceability and validation differ for network protection functionality assessment. The specification for network protection devices calls for general, configurable, extensible capabilities rather than specific settings or protocols. Validation MUST take account of the following tenets:
    - Tests must employ sampling methods to provide evidence that the required capability exists and functions properly.
    - The requirements that various capabilities be administratively configurable imply that a sizeable proportion of the tests will involve demonstration of administrative interfaces and hence less amenable to automation or scripting.
    - Some level of penetration testing is needed to demonstrate the assurance aspects of some of the requirements, such as security of administrative controls.
    - Testing the performance under load/fail safe requirements will require sufficient test traffic generation capacity to reach the design limits of the device being tested.
- Given that live testing of NPDs involves exploratory testing over and above execution of the written tests, the reference test suite may be shown to be correct but not complete. Section 6.2 below documents the completion of an executable test suite instance.

[6] Enumerate these in an appendix.

4.3 A Statement of Measurement Uncertainty

The Base Specifications referenced by the USGv6 profile [2] are informally written to include assertions of functionality using imperative statements and modal verbs MUST, SHOULD, MAY, and NOT. Tests are informally constructed procedures that mimic the behavior prescribed by the specifications. This is not inherently a quantitative activity. Exhaustive testing is not possible and uncertainty exists according to the shortfall in ideal coverage. Given that ISO 9646-2 10.4 [10] specifies ideal coverage of a test suite, the test laboratory MUST quantify this shortfall and use this as the measure of uncertainty for a test method.

4.4 Test Feedback Mechanisms

The abstract test specifications initially approved as the reference tests will still have errors and omissions. These will be uncovered in the course of testing experience. There may also be differences of interpretation. It is important that test methods be improved in a timely fashion. It is also important that corrupted tests not affect the overall integrity of results. Corrupted tests will be addressedby community and stakeholder agreement. Subject to agreement, they may be withheld from the test base until the next revision, or retained for continuous use. While the test base is volatile, IPv6 product developers should be prepared to revise their products to meet current test requirements, and enhance interoperability going forward.

The community and stakeholders in this context includes representatives of IPv6 device producers, users and the testing industry. Consistency of interpretation is essential to the quality of the aggregate testing and the stakeholders confidence that compliant devices will meet users needs.

The mechanism for achieving feedback includes discussion and agreement on test interpretations and test specifications, through a mail group: usgv6-testing@antd.nist.gov. All test developers and test laboratories engaged in testing with respect to the USGv6 testing program MUST actively participate in this mail group.

5 Test Methods and Scopes of Accreditation

The term test method refers to the executable realization of an abstract test specification, and may be associated with one or more RFCs and other standards referred to as base specifications. These may differ for the testing modes of conformance, interoperability and network protection. A laboratory's scope of accreditation is the discrete technical method identified by an accreditor as the method that will be assessed and audited during the accreditation process. At a minimum, one scope of accreditation is required for a laboratory to be eligible for participation under this program. The IPv6 device types identified in the USG IPv6 Profile are reiterated here, in Section 5.1. The scopes of accreditation are described here in terms of their test methods in Section 5.2. The permissible combinations, and their restrictions, follow in Section 5.3.

5.1 Summarization of Device Types

There are three types of devices in this profile: hosts, routers and network protection devices, defined as:

1. **Router:** a node that interconnects subnetworks by packet forwarding.

2. **Host:** any node that is not a router. In general this profile is limited to discussions of general purpose computers, and not highly specialized devices.

3. **Network Protection Devices: f**irewalls and intrusion detection / prevention devices that examine and selectively block or modify network traffic.

Since this profile is aimed at general purpose computing devices, no attempt is made to exhaustively list the many possible configurations of host and router.

5.2 Scopes of Accreditation

A laboratory's scope of accreditation comprises the set of test methods claimed among its competence. The arrangement of test methods is largely determined by the technology and the scope of accreditation is organized by the accreditor under a modularizing principle that respects the integrity of the technology as well as the accreditor's ability to source technical assessment capabilities at a realistic granularity of competence. The test methods for conformance, interoperability and network protection functions are listed below. For conformance and interoperability it is felt useful to combine all the methods applicable to the compendium of USGv6-v1-capable requirements for hosts and routers, as well as separately enumerating the individual methods.

5.2.1 Conformance Test Methods

Method H1: USGv6-V1-Capable Host Requirements

- **IPv6 Basic Requirements** – see USG profile Section 6.1.
  - **SLAAC** – require support of stateless address auto-configuration.
  - **DHCP-Client** – require support of stateful (DHCP) address auto-configuration.
- **Addressing Requirements** – see USG profile Section 6.6.
- **IP Security Requirements** – see USG profile Section 6.7.
  - **IPsec-V3** – require support of the IP security architecture.
  - **IKEv2** – require support for automated key management.

    - **ESP** – require support for encapsulating security payloads in IP.
- **Multicast Requirements** – see USG profile Section 6.9.
- **Link Specific Technologies** – see USG profile Section 6.5.
    - **Link** – require support of 1 or more link technologies.

Method R1: USGv6-V1-Capable Router Requirements

- **IPv6 Basic Requirements** – see USG profile Section 6.1.
    - **DHCP-Client** – require support of stateful (DHCP) address auto-configuration.
- **Addressing Requirements** – see USG profile Section 6.6.
- **IP Security Requirements** – see USG profile Section 6.7.
    - **IPsec-V3** – require support of the IP security architecture.
    - **IKEv2** – require support for automated key management.
    - **ESP** – require support for encapsulating security payloads in IP.
- **Network Management Requirements** – see USG profile Section 6.8.
    - **SNMP** – require support of network management services.
- **Multicast Requirements** – see USG profile Section 6.9.
- **Quality of Service Requirements** – USG profile see Section 6.3.
    - **DS** – require support of Differentiated Services capabilities.
- **Link Specific Technologies** – see USG profile Section 6.5.
    - **Link** – require support of 1 or more link technologies.

Method F1: IPv6 Basic Requirements – see USG profile Section 6.1.

Method F2: Stateless Address Auto-configuration – see USG profile Section 6.1.

- **SLAAC** – require support of stateless address auto-configuration.

Method F3: Privacy extensions for IPv6 SLAAC Requirements – see USG profile Section 6.1

- **PrivAddr** – require support of SLAAC privacy extensions.

Method F4: DHCP Client – see USG profile 6.1.

- **DHCP-Client** – require support of stateful (DHCP) address auto-configuration.

Method F5: Prefix Delegation – see USG profile Section 6.1.

- **DHCP-Prefix** – require support of automated router prefix delegation.

Method F6: Secure Neighbor Discovery Requirements – see USG profile Section 6.1.

- **SEND** – require support of neighbor discovery security extensions.

Method F7: Addressing Requirements – see USG profile Section 6.6.

Method F8: Cryptographically Generated Addresses – see USG profile Section 6.6.

- **CGA** – require support of cryptographically generated addresses.

Method F9: DNS Client – see USG profile Section 6.11.
- **DNS-Client** – require support of DNS client/resolver functions.

Method F10: Socket API for IPv6 – see USG profile Section 6.11.
- **Sock** – require support of Socket application program interfaces (**Host only**).

Method F11: URI Generic Syntax – see USG profile Section 6.11.
- **URI** – require support of IPv6 uniform resource identifiers.

Method F12: DNS Server Functions – see USG profile Section 6.11.
- **DNS-Server** – require support of a DNS server application.

Method F13: DHCP Server Functions – see USG profile Section 6.11.
- **DHCP-Server** – require support of a DHCP server application.

Method F14: Interior Routing Protocol– see USG profile Section 6.2.
- **IGW** – require support of the intra-domain (interior) routing protocols (**Router only**).

Method F15: External Routing Protocol– see USG profile Section 6.2.
- **EGW** – require support for inter-domain (exterior) routing protocols (**Router only**).

Method F16: IP Security Requirements – see USG profile Section 6.7.
- **IPsec-V3** – require support of the IP security architecture.
- **IKEv2** – require support for automated key management.
- **ESP** – require support for encapsulating security payloads in IP.

Method F17: Internet Key Exchange Requirements – see USG profile Section 6.7.
- **IKEv2** – require support for automated key management.

Method F18: Transition Mechanism Requirements – see USG profile Section 6.4.
- **IPv4** – require support to enable interoperation with IPv4-only systems.

Method F19: IPv6 Provider Edge MPLS Tunneling – see USG profile Section 6.4.
- **6PE** – require support of tunneling IPv6 over IPv4 MPLS services (**Router only**).

Method F20: Network Management Requirements – see USG profile Section 6.8.
- **SNMP** – require support of network management services.

Method F21: Multicast Requirements – see USG profile Section 6.9.

Method F22: Source-Specific Multicast for IP Requirements – see USG profile Section 6.9.
- **SSM** – require full support of multicast communications.

Method F23: Mobility Requirements – see USG profile Section 6.10.

- **MIP** – require support of capability for this host to be a mobile node.

Method F24: NEMO Basic Support – see USG profile Section 6.10.

- **NEMO** – require support of mobile network capabilities (**Router only**).

Method F25: Quality of Service Requirements – USG profile see Section 6.3.

- **DS** – require support of Differentiated Services capabilities.

Method F26: Explicit Congestion Notification (ECN) to IP – USG profile see Section 6.3.

Method F27: Link Specific Technologies – see USG profile Section 6.5.

- **Link** – require support of 1 or more link technologies.

Method F28: Packet Compression Technology Requirements– see USG profile Section 6.5.

- **ROHC** – require support of robust packet compression services.

5.2.2 Interoperability Test Methods

Interoperability test methods and scopes of accreditation are organized in the identical manner as conformance test methods. The actual tests applicable are different of course.

5.2.3 Network Protection Test Methods

USGv6-V1 NPD Requirements:

– **Network Protection Device Requirements** – see USGv6 profile Section 6.12 [2].

- – **FW** – require support of basic firewall capabilities.
- – **APFW** – require support of application firewall capabilities.
- – **IDS** – require support of intrusion detection capabilities.

5.3 Combinations and Restrictions

1. There are test methods and scopes of accreditation for conformance, interoperability and network protection.
2. In general, test laboratories may be 1st, 2nd or 3rd party. A 1st party laboratory is associated with the product vendor. A 2nd party laboratory is associated with an acquisition authority. A 3rd party laboratory is independent.
3. 1st, 2nd and 3rd party laboratories may perform one or more conformance testing methods. A 1st party laboratory may offer 3rd party services for conformance testing to other vendors.
4. 2nd and 3rd party laboratories may perform one or more interoperability test methods, or one or more network protection test methods. Any results of interoperability testing by a 1st party laboratory will not be recognized by the USGv6 testing program.
5. A single IPv6 device may complete the USG testing requirements in multiple test laboratories, considering their accreditation scopes for different functional categories.

6 Test Method Validation

As a step in the traceability of tests described in Section 4, the results of using executable test methods MUST be traceable to the reference test specifications. This requires validating the results to ensure that they match the expected outcomes. The test laboratory is responsible to ensure validation is done, but this may actually be performed in an external, accredited laboratory or by a consortium of accredited test laboratories and test method developers. Validation of conformance and interoperability test systems is functionally equivalent and procedures for these are given in Section 6.1. Validation procedures for Network Protection are discussed in Section 6.2.

6.1 Conformance and Interoperability Test Method Validation

In addition to the method and objective of validation for conformance and interoperability given here, additional requirements are levied for the test capture and report structure.

Method:

Conformance and interoperability executable test methods must conform to the latest released abstract test specifications or reference tests. These test methods may be validated using the procedures below:

1) Executable test methods per each abstract test specification may be cross-examined by an accredited laboratory, a consortium of accredited laboratories, or a consortium of test method developers with applicable technical knowledge to ensure comparable testing results.
2) Cross-examination Procedure:

The laboratory may use the “golden node” method in order to obtain a set of results. (Refere to the test capture file and report structure requirements below). This is defined as follows:

> Two or more instances of a designated IPv6 node subject to the same testing procedures using different test tools shall produce comparable results. This method is ideal for when two or more test tools exist for a given abstract test specification.

This testing is typically against an open source or freely available implementation. The implementation may not pass 100% however the test procedures and observable results MUST be comparable to the abstract test specification.

a) If one executable test method exists, a single technical expert may examine the test results.
b) If multiple executable test methods exist, all test results should be comparable and consistent.

The cross-examiner shall send comments to the laboratory if deviation from the abstract test specification was observed. The laboratory will have ability to comment and action must be taken to resolve the comments before test method acceptance. Action may result in a change to the abstract test specification, change in executable test tool or no change necessary. The resolution SHOULD be a consensus between the cross-examiner and laboratory(s). Alternative technical experts may be requested if consensus can not be achieved.

1) Each test method per abstract test specification may be validated against an approved test tool designed to examine the executable results. This test tool must be developed by an alternative laboratory or facility.

2) All accredited test laboratories MUST participate in interlaboratory comparisons. Refer to Section 7.

Test Capture File Structure:
In order to facilitate comparison of results, the use of a common file format is extremely convenient. Each test procedure that produces a capture result must be saved as a capture dump file in PCAP format [17]. The test capture result files must be named using the test number and extension. For example, Test 1.1 should have a corresponding test capture result 1.1.cap file.

Report Structure:
Each test method must produce a reporting capability that illustrates the test number and title along with result, typically indicated by a Pass or Fail notation. The USGv6 test selection tables associated with the test specifications [14] offer a model for this.

Objective: To ensure that the procedures and observable results as listed in the reference tests are packet-for-packet and test-for-test comparable between executable test methods under validation.

6.2 Network Protection Test Method Validation

For the time being test capture and report structure requirements are not levied here. If they are found necessary to the operation of the program they will be identified at the USGv6 testing program website [14].

Method:

1) NPD abstract test suites represent the minimum compliant set. Executable procedures MUST be traceable to these tests.
2) Validation of this set occurs by execution against one or more sample implementation, and reconciliation of the results by two or more independent domain experts.
3) Additional exploratory tests may be constructed and executed at the time of testing.
4) The final test suite executed for a network protection device is known at the completion of testing. Validation taking account of the traceability procedures in section 4.1.2 MUST be conducted prior to issuance of the test report.
5) Every exploratory test MUST be traceable to the base specification and documented as such.

Objective:

1) To ensure that the results of executing every test in the common reference set are procedurally and syntactically compatible among all laboratories accredited for this method.
2) To ensure that the results of executing every exploratory test are traceable to the specification in the USG profile 6.12.

7 Proficiency Testing and Interlaboratory Comparisons

Assessment for accreditation requires a laboratory to demonstrate its competence with the test methods in its scope of accreditation. The USGv6 testing program follows ISO/IEC Guide 43 [18] and distinguishes between proficiency testing for test method competence and proficiency testing for interlaboratory comparison.

- During assessment for accreditation proficiency testing is conducted by the accreditation body where the laboratory staff proficiency with the domain area, test methods, test tools and associated quality procedures is assessed. This testing may be conducted prior to, during or outside the on-site assessment using methods listed in ISO/IEC guide 43 [18].
- It is a requirement of the USGv6 testing program that the results of testing in any and every accredited laboratory be field-for-field, packet-for-packet and test-for-test comparable. This is established via a system of interlaboratory comparisons. This is accomplished by sending to accredited laboratories sample test items for them to test and return, or by other methods selected from IOS/IEC guide 43 [18]. The results are independently assessed, and the results from each participating laboratory MUST agree. In the event that test results are discrepant a systematic resolution process is taken:

    - A pure laboratory proficiency problem will trigger accreditor action, up to and including a spot-check on-site assessment.
    - Ambiguities in test interpretation will trigger the USG IPv6 community resolution process.

Considering that there may be more than one laboratory accreditation body establishing a program for IPv6 laboratories, the USGv6 testing program will designate a single organization to conduct specific proficiency testing activities for interlaboratory comparisons. If necessary and practical the USGv6 testing program may designate different organizations for different specific proficiency testing activities, Organizations providing proficiency testing for interlaboratory comparisons will meet the requirements of ISO/IEC guide 43 [18].

8 Claims of Product Compliance

IPv6 product compliance in the USG program is attested to by a Suppliers Declaration of Conformity (SDOC) based on test results conducted in an accredited laboratory and supported by an overall summary of capabilities and on the check list from Appendix A of the profile. This section discusses the general requirements for claiming SDOC in Section 8.1 and the test pass requirements in Section 8.2 that underpin the documentary basis for the attestation.

8.1 Suppliers Declaration of Conformity

A product vendor who seeks to test in an accredited laboratory MUST submit a list of the functions claimed. This list MUST include all of the unconditional must requirements for a device, plus those musts that are conditional on options required for a particular procurement request. The conditions and configuration options are defined in the host, router and network protection device templates in Sections 3, 4 and 5 of the USGv6 profile [2].

8.2 Test Pass Requirements

The minimal mandatory set of IPv6 capabilities for each device category (host, router and network protection device) is defined by the corresponding unconditional MUSTs in the Node Requirements Table. This set of requirements defines the minimal capabilities of a host, router, or NPD that claims to be "USGv6-V1-Capable" (see the USGv6 profile [2], Section 7.2 Compliance).

IPv6 device suppliers may be offering products that offer vendor specific functionality packages that go beyond the above specified minimum and these will be reflected in claims of feature support. Every product that is associated with a SDOC MUST have evidence of passing:

- The unconditional MUST functions listed in the Node Requirements Table. This entails passing tests of the MUST requirements in each RFC so listed.
- For every functional category claimed in the SDOC the conditional MUST functions listed in the Node Requirements Table. This entails passing the MUST requirements in each RFC so listed.
- For every RFC listed as SHOULD in the Node Requirements Table and claimed in the SDOC, the MUST requirements within the specification MUST be passed.

At any stage in the evolution of of the USGv6 Profile and testing program, the test infrastructure will be continuously improved. This means there are functions and RFCs specified in the Profile, for which a Test Specification is not yet available. In these cases the developer MUST be able to identify such testing as was done.

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